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ORIGINAL ARTICLE

Magnetohydrodynamic convective-radiative oscillatory flow of a chemically reactive micropolar fluid in a porous medium

Dulal Pal[a,*], Sukanta Biswas[b]

[a]*Department of Mathematics, Visva-Bharati University, Siksha-Bhavana (Institute of Science), Santiniketan, West Bengal 731235, India*
[b]*Mathematics Department, Ananda Mohan College, Kolkata, West Bengal 700009, India*

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Abstract This paper deals with the investigation of double-diffusive heat and mass transfer characteristics of an oscillatory viscous electrically conducting micropolar fluid over a moving plate with convective boundary condition and chemical reaction. The non-linear partial differential equations are first converted into nonlinear ordinary differential equations by means of perturbation analysis and the governing equations are solved analytically. The effects of magnetic field, chemical reaction, permeability parameter, Prandtl number, Schmidt number, thermal radiation and viscosity parameter are analyzed on skin friction, Nusselt number, velocity, and temperature & concentration distributions. It is observed that the concentration profiles decrease with increase in the dimensionless time and increase with increase in the chemical reaction parameter. It is also observed that the velocity profile increases with increase in time but reverse effects are found by increasing the value of the viscosity ratio parameter. Further, it is seen that the effect of magnetic field parameter is to increase the micro-rotational velocity profiles but reverse effect is observed by increasing time.

*Corresponding author. Tel./Fax: +91 3463 261029.

E-mail addresses: dulalp123@rediffmail.com (Dulal Pal), sukantavb@gmail.com (Sukanta Biswas).

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Nomenclature

A	small real positive constant
B_0	externally imposed transverse magnetic field strength, gauss meter
C	concentration of the fluid (uint: $\mathrm{mol \cdot m^{-3}}$)
C_∞	free stream concentration (uint: $\mathrm{mol \cdot m^{-3}}$)
C_f	frictional coefficient
$C_\omega^{'}$	local couple stress coefficient at the wall
c_p	specific heat at constant pressure (uint: $\mathrm{J \cdot kg^{-1} \cdot K^{-1}}$)
D	molecular diffusivity (uint: $\mathrm{m^2 \cdot s^{-1}}$)
Gr	local Grashof number
g	acceleration due to gravity (uint: $\mathrm{m \cdot s^{-1}}$)
G_{rT}	thermal Grashof number
G_{rC}	mass Grashof number
j^*	microinertia per unit mass (uint: $\mathrm{m^2}$)
j	dimensionless microinertia per unit mass
K	permeability parameter (uint: $\mathrm{m^2}$)
K_1^*	mass absorption coefficient (uint: $\mathrm{m^{-1}}$)
K_2	dimensionless permeability parameter
M	magnetic field parameter
n	frequency parameter (uint: Hertz)
n_1	parameter related to micro-gyration vector and shear stress
Nu	local Nusselt number
Pr	Prandtl number
q_r^*	thermal radiative heat flux (uint: $\mathrm{W \cdot m^{-2}}$)
Re_x	local Reynolds number
r	radiation parameter
Sc	Schmidt number
Sh_x	Sherwood number
T	temperature of the fluid (uint: K)
T_∞	free stream temperature (uint: K)
T_ω	temperature at the wall (uint: K)
t^*	dimensional time (uint: s)
t	dimensionless time
u^*	velocity component in x-direction (uint: $\mathrm{m \cdot s^{-1}}$)
u	dimensionless velocity component in x-direction
U_0	free stream velocity (uint: $\mathrm{m \cdot s^{-1}}$)
u_p^*	uniform velocity of the fluid in its own plane (uint: $\mathrm{m \cdot s^{-1}}$)
U_p	dimensionless velocity of the plate
V_0	scale of suction velocity at the plate (uint: $\mathrm{m \cdot s^{-1}}$)
v^*	velocity component in y-direction (uint: $\mathrm{m \cdot s^{-1}}$)
v	dimensionless velocity component in y-direction
x, y	distance along and perpendicular to the plate, respectively (uint: m)

Greek symbols

α	thermal diffusivity (uint: $\mathrm{m^2 \cdot s^{-1}}$)
β	dimensionless viscosity ratio
β_C	coefficient of mass expansion of the fluid (uint: $\mathrm{K^{-1}}$)
β_T	coefficient of thermal expansion of the fluid (uint: $\mathrm{K^{-1}}$)
γ	spin gradient viscosity (uint: $\mathrm{kg \cdot m \cdot s^{-1}}$)
γ_1^*	chemical reaction parameter
γ_1	dimensionless chemical reaction parameter
ε	small positive quantity
θ	dimensionless temperature of the fluid
η	similarity variable
μ	coefficient of viscosity
υ	kinematic viscosity (uint: $\mathrm{m^2 \cdot s^{-1}}$)
υ_r	kinematic rotational viscosity (uint: $\mathrm{m^2 \cdot s^{-1}}$)
ρ	density of the fluid (uint: $\mathrm{kg \cdot m^{-3}}$)
σ	electrical conductivity of the fluid (uint: $\mathrm{S \cdot m^{-1}}$)
σ^*	Stephan-Boltzmann constant (uint: $\mathrm{W \cdot m^{-2} \cdot K^{-4}}$)
ω^*	component of angular velocity (uint: $\mathrm{m^2 \cdot s^{-2}}$)
ω	dimensionless component of angular velocity
Λ	coefficient of vortex viscosity (uint: $\mathrm{kg \cdot m^{-1} \cdot s^{-1}}$)
κ	thermal conductivity of the fluid (uint: $\mathrm{W \cdot m^{-1} \cdot K^{-1}}$)
λ	heat generation/absorption parameter
ϕ	concentration distribution

Superscript

$'$	differentiation with respect to y

1. Introduction

In recent years. the study of heat and mass transfer in micropolar fluid has been considered extensively due to their occurrences in several industrial applications. The investigation of convective heat and mass transfer in Newtonian and non-Newtonian fluids can be extensively used in polymer production and in a number of industrial applications such as fiber and granular insulation, geothermal systems, glass-fiber and paper production, cooling of metallic sheets, geothermal reservoirs, thermal insulation, enhanced oil recovery, packed bed catalytic reactors etc. The theory of micropolar fluid given by Eringen [1] described the characteristics of polymeric fluids, liquid crystals, animal blood etc. Extensive research works have been carried out to study heat and mass transfer in a micropolar fluid past a semi-infinite plate under different boundary conditions. Motsa et al. [2] examined numerical analysis of mixed convection magnetohydrodynamic heat and mass transfer past a stretching surface in a micropolar fluid-saturated porous medium in the presence of Ohmic heating and they noticed that the fluid velocity increases with increase in the Grashof numbers and the fluid temperature increases with increasing values of magnetic field. Ferdows et al. [3] examined hydromagnetic convection heat transfer in a micropolar fluid over a vertical plate and they conclude that the local skin-friction coefficient and the local Nusselt number decreases with an increase in the value of the magnetic parameter. Gupta et al. [4] studied unsteady mixed convection flow of micropolar fluid over a porous shrinking sheet and they found that a fast rate of cooling can be achieved by Eckert number. Pal [5]

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